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SUBJECTIVE MEASUREMENT OF TACTICAL AIR COMMAND AND CONTROL--VOL. I: BACKGROUND AND APPROACH

Monti Callero, Willard Naslund,
Clairice T. Veit

March 1981

N-1671/1-AF

Prepared For

The United States Air Force

Rand
SANTA MONICA, CA. 90406

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PREFACE

This is the first in a series of Rand Notes describing the application of a newly formulated subjective measurement method to the evaluation of tactical air command and control. It presents an overview of command and control evaluation and the subjective measurement method and details the evaluation problem being addressed and its conflict environment. Other Notes in the series, sequentially numbered, describe the conduct and results of the evaluation. The research is being done under the Project AIR FORCE-sponsored project "Tactical Air Command and Control."

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ABSTRACT

We have developed a subjective measurement method for evaluating complex systems and are applying it to the evaluation of tactical air command and control. This paper addresses the major issues of command and control evaluation and describes the newly formulated Subjective Transfer Function (STF) approach and how it will be applied to a specific problem concerning the value of information in effective employment of tactical air. The STF approach stresses the idea of hypothesis testing so that conclusions about system effects on important outcomes are based on tested and verified premises. The approach has application to evaluation of complex systems in general. Other volumes in the series will describe the conduct and results of the command and control evaluation.

SUMMARY

Evaluating the contribution of command and control to the overall combat effectiveness of a military force poses one of the most difficult problems in military analysis. Thus far, the two most common evaluation approaches, computer simulation and military exercises, have not measured up to the task, nor can they be expected to in the near future. As part of a research effort to develop command and control evaluation methodology, we have formulated a subjective measurement method that we call the Subjective Transfer Function approach to complex system analysis. This approach can be applied to a broad range of tactical air command and control evaluation problems.

The use of subjective measurement to evaluate tactical air command and control is based on the concept that human perceptions of effectiveness (particularly the perceptions of command and control "experts") relate to true effectiveness. And further, factors or conditions that change perceptions of effectiveness are key to what changes actual effectiveness. The subjective transfer function approach yields credible conclusions about human perceptions by basing conclusions on tested perceptual hypotheses.

We are currently demonstrating and refining the approach by conducting an investigation that addresses realistic command and control and force employment problem situations. The demonstration problem was selected in conjunction with Air Force personnel from the Tactical Air Command, the Tactical Air Forces Interoperability Group (TAFIG) and Headquarters, Air Force, Studies and Analysis. It examines the value of

enemy information to the effectiveness of command and control in employing tactical forces and evaluates the effects of different levels of information about enemy ground forces on the ability of tactical air command and control to use tactical air effectively against enemy second echelon targets in a Korea-like theater conflict. Effective use of tactical air will be considered in terms of favorable influence on the outcome of the land battle.

This note sets the stage for a series of notes describing the conduct of the investigation. In it we discuss command and control evaluation in general and subjective measurement in particular and present an overview of the subjective transfer function approach (reported in detail in Veit and Callero, 1981). Finally, we describe the conflict environment used as a backdrop for the demonstration problem.

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I. INTRODUCTION

Tactical air command and control is the means by which an air commander brings tactical air forces to bear against an enemy in war.

Evaluating the contribution of command and control to the overall combat effectiveness of a military force poses one of the most difficult problems in military analysis. Command and control and their conflict environment have broad scope and complexity. Cause and effect relationships are obscure, as are criteria for effectiveness. And conceptual and technical difficulties are exacerbated by the dominance of human decision processes. Thus far, traditional analytical approaches to evaluation (e.g., computer simulation and military exercises) have been incapable of the task.

As part of a research effort to develop command and control evaluation methodology, we have formulated a subjective measurement method that we call the Subjective Transfer Function approach to complex system analysis. We are currently demonstrating and refining this approach by conducting an investigation that addresses realistic command and control and force employment problem situations. The investigation is being conducted in conjunction with the Air Force.

In the remainder of this section we briefly discuss tactical air command and control and evaluation. Section II summarizes subjective measurement issues. Section III describes our approach to developing a subjective measurement method that resolves those issues and overviews our Subjective Transfer Function approach. Section IV contains an

exemplary conflict environment we are using as a backdrop for an investigation to demonstrate and refine the approach.

TACTICAL AIR COMMAND AND CONTROL

Tactical air command and control provides the linkage between operational requirements and the tactical air resources available to meet them. This idea is outlined in Fig. 1. In this perspective, tactical air operational requirements arising in the course of conflict are met with the application of tactical air resources by the command and control process. The command and control process is also the means for operational management of the air resources. Air resources must be maintained at a status capable of supporting the application decisions and the resultant tactical air operations. Hence, tactical air command and control spans both operations and resources and bridges and balances

```
  TACTICAL                                   TACTICAL AIR
    AIR                                      OPERATIONAL
  RESOURCES                                  REQUIREMENTS
     |                                            |
     |                                            |
 Operational                                    Force
 Management                                  Application
     |                 TACTICAL AIR               |
     |--------------- COMMAND AND -------------|
                         CONTROL

 <-------------Tactical Air Employment------------->
```

Fig. 1--Tactical air resource employment

the two by managing the resources and applying the force to combat needs.

Tactical air command and control may be viewed as constituted from elements of doctrine, organizational structure, procedures, personnel, facilities, equipment, and communications. These elements give to those responsible at each level of command the ability to perform the functions of planning, directing, and controlling necessary to accomplish their purpose of meeting mission objectives through the performance of tactical air operations. Not only does meeting mission objectives require the conduct of effective tactical air operations, but even more important, it requires the selection of tactical air operations most appropriate to those objectives. For example, tactical air operations must be chosen and conducted so as to have a favorable effect on major military actions, such as land battles. A representation of this interrelationship is shown in Fig. 2.

Some important observations can be made from this representation. The elements that make up the command and control system and bound its capability are the inputs to the overall process. They alone have well-defined, measurable attributes (e.g., quantity, performance factors, physical characteristics) that taken together describe a command and control system. Only the elements can be added to, reconfigured, and modified to produce variations in the capabilities of command and control.

Effective tactical air operations and favorable effects on major military actions are the outputs. Hence, the crucial products of command and control are its contributions to those outputs. The inputs

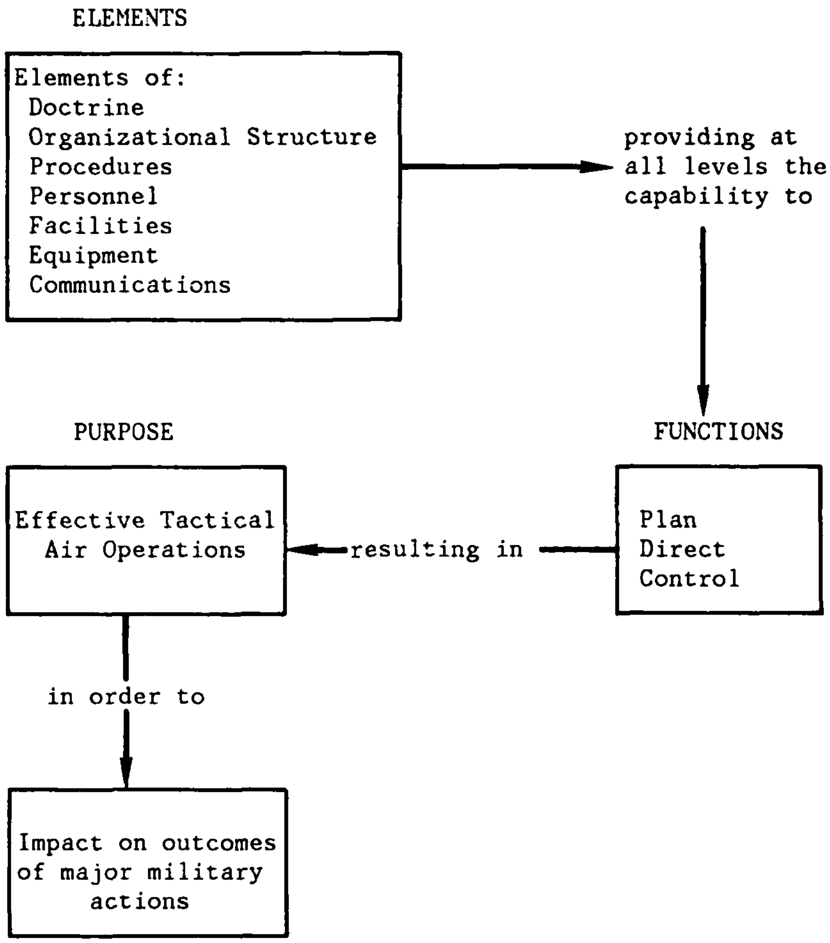

Fig. 2--Tactical air command and control

(the elements) do not affect the outputs directly, but indirectly through the functions, and the functions are human dominated processes. Planning, directing, and controlling use the elements and what they provide, but plans, directions, and control actions are the results of decisions made by people.

This dominant human element in the command and con*rol process has major implications in the development of evaluation methodology.

COMMAND AND CONTROL EVALUATION

What we seek in an evaluation methodology is to determine the relationship between command and control capabilities and effective use of air resources. Or, in terms of the above representation, the goal is to relate the inputs to the outputs--the elements to the employment effects--by determining what happens between them.

Although any particular evaluation of command and control will necessarily be tailored to the specific context and purpose of the questions or issues that generate the evaluation requirement, there are three broad areas of interest from which an evaluation requirement would probably be generated. One is the _internal operation of the command and control system_, which emphasizes the efficiency of the system in executing its assigned functions. The second is the _operational arena_, which concentrates on the ability of a fielded command and control system to support tactical air operations requirements. And the third is the _management decision process_, which focuses on the selection and acquisition of major alternatives to support the performance of command and control functions. Within these three interests is the need to relate command and control capabilities to the effective use of the tactical air resources.

Traditional evaluation methodologies can be categorized into three approaches--_computer modeling and simulation_, which applies abstractions of the problem domain in the form of computer programs for representation and analysis; _operational exercises_, which use command and control elements directly in a simulated conflict environment; and _subjective analysis_, which is based upon human judgment. Although

greatly different technically, the three have much in common conceptually. Each requires abstraction of real world processes and situations, determination of causal relationships, comprehension and representation of conflict, and comprehension and representation of decisionmaking. The feasibility and utility of a method depend to a great extent on how it can accommodate these requirements.

We briefly discuss computer modeling and simulation and operational exercises as potential evaluation methodologies before we address subjective analysis at length.

Computer modeling and simulation have been used for evaluating a wide variety of systems, ranging from social to mechanical. The Air Force and the other services have used them extensively to evaluate military systems in a conflict environment. Conflict models emphasizing engagement outcomes have evolved over the years to where they have achieved a measure of acceptance within the military community. A comparable evolution of command and control modules within these models has not occurred, partly because of the difficulty of effectively representing command and control systems. But the most difficult barrier has been the general lack of understanding (at least in the form necessary to permit it to be made part of a computer model) of the command and control decisionmaking process--of how information is translated into decisions. As yet, the computer modeling approach has not adequately represented the basic functions of the command and control process--planning, directing, and controlling--and there appears to be no workable way to overcome this deficiency within the current state of the art.

Operational exercises emphasizing command and control[1] have the potential to provide an evaluation environment closer to actual war than anything except war itself.[2] People perform the command and control functions within actual facilities using actual equipment and communications under simulated conflict conditions. However, in order to realize the evaluation potential of operational exercises, the complex interactions between command and control and the conflict environment must be simulated in a valid and verifiable manner. Currently, this simulation is attempted by a control team using primarily manual methods, limiting the realism of the simulated conflict environment, mainly because of bookkeeping and calculation limitations. So much effort and memory capacity are necessary to provide the inputs to simulate a large-scale conflict that, in current manual exercises, most of the play must be scripted well in advance; thus, actions taken by the players generally have little effect on the course of events.[3] Little is gained by this method in attempting to evaluate tactical air command and control capabilities with respect to their effect on actual force employment.

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[1]By this we mean exercises that do not include the use of actual combat forces such as aircraft and other weapon systems or ground maneuver units.

[2]An exercise designed to train or evaluate tactical air command and control systems should be set in a theater environment matching the scope of tactical air operational requirements. In such a simulated setting, combat force play is grossly artificial because of time, cost, and safety constraints, a fact that is obvious to all participants, particularly those involved with command and control.

[3]This circumstance has been acceptable, if not desirable, because typically, operational exercises are conducted primarily for procedural training of personnel and to obtain some nonrigorous "insights" into the capabilities and limitations of the systems and forces involved. These goals do not require high fidelity environments.

Current computer simulations and manual exercises both have serious limitations when they are used as a basis for the study and evaluation of command and control processes. The approaches, however, are complementary, in that each possesses the potential for offsetting the deficiencies of the other. This complementarity has led us to develop a concept and preliminary design overview for a Computer-Aided Exercise Facility for tactical air command and control evaluation and training (Callero, Strauch, and Lind, 1980). It calls for an appropriate combination of automated conflict environment and command post exercise.[4] The basic idea is to create a conflict environment in which computer simulation represents the physical processes of conflict and humans make the decisions in the actual (or close replica of) surroundings they would find themselves in during wartime. Evaluation information would be generated by conducting appropriately designed exercises in this mode.

Although we feel that a Computer-Aided Exercise Facility could provide the basis for conducting tactical air command and control evaluation, it will take at least two to three years to develop and evolve it sufficiently within the framework of scientifically rigorous evaluation designs.

We turn our attention now to the third potential methodology, subjective measurement, and describe our effort to develop a subjective measurement approach that meets our evaluation goals.

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[4]The Computer-Aided Exercise Facility concept is being further developed by the Air Force for possible implementation as a Tactical Force Management Training and Analysis Facility at the C3I complex, Hurlburt Field, Florida.

II. SUBJECTIVE MEASUREMENT GOALS AND CURRENT APPROACH DEFICIENCIES

The use of subjective measurement to evaluate tactical air command and control is based on the concept that human perceptions of effectiveness (particularly the perceptions of command and control "experts") relate to true effectiveness. And further, factors or conditions that change perceptions of effectiveness are key to what changes actual effectiveness.

The subjective measurement method used to evaluate command and control must yield credible conclusions about experts' perceived effectiveness. For conclusions to be credible, the method must provide for the collection of human judgments about tactical air command and control and resultant tactical force employment so that conclusions about perceived effectiveness stem from tested premises. Thus, the method must provide a way to test perceptual hypotheses about real tactical air command and control and force employment problems.

We first illustrate the goals of subjective measurement evaluations by using an example of a small tactical air command and control problem and then discuss flaws in subjective measurement methods currently being used to address such problems. The methodological flaws in these approaches have led us to develop a subjective measurement approach that eliminates them.

GOALS IN SUBJECTIVE MEASUREMENT EVALUATIONS

To illustrate major goals in subjective measurement evaluation, we use an example problem in tactical air command and control.

Example Problem

Suppose a decision was being made about selecting an information display capability for use in the Combat Plans Division of the Tactical Air Control Center, and it was desired to determine how experienced mission planners judge what effect different information display capabilities would have on their ability to plan interdiction missions.

In structuring this problem, one might hypothesize that the quality of the friendly and enemy information available to be displayed, as well as the display capability, affects judgments by experts about the ability to plan interdiction missions. An initial representation of this problem domain is shown in Fig. 3.

The hierarchical structure shown in Fig. 3 suggests that planning interdiction depends upon three components--friendly information, enemy information, and information display. Specifically, we hypothesize that the ability to plan interdiction has a relationship to the quality of

```
                     Ability to Plan
                      Interdiction
                           |
                           |
                     (Relationship)
                           |
                           |
        ---------------------------------
        |                  |                 |
        |                  |                 |
   Quality of         Quality of       Information
    Friendly            Enemy            Display
   Information       Information        Capability
    Available          Available
```

Fig. 3--Example problem representation

friendly information available to the planners, the quality of enemy information available to the planners and the information display capability by which the information is presented to the planners.

Subjective Measurement Goals

In the above example, subjective measurement goals would be to determine:

1. The relevancy of the components selected to define the problem;
2. The relationship between the selected components and the expert's judged ability to plan interdiction;
3. The subjective values that the expert places on these components with regard to the ability to plan interdiction.

In other domains, the major goals of a subjective measurement evaluation are also to determine the relevancy of components in terms appropriate to the system being evaluated, relationships among components, and subjective values placed on components by respondents.

We next briefly describe why subjective measurement techniques that are typically applied in such analyses fail to meet these goals.

FLAWS IN CURRENT APPLICATIONS OF SUBJECTIVE MEASUREMENT

Subjective measurement techniques currently being used to make the determinations listed above have methodological flaws that preclude

interpretation of their results as reflecting respondents' perceptions.[1] The problems with these techniques can be outlined as follows.

First, the representation (components and linkages, as illustrated in Fig. 3) remains fixed throughout the system's evaluation. The current methods do not provide a way to determine if a selected component is appropriate--that is, if the component actually influences respondents' judgments. Thus, there is no way of knowing if hypothesized components should be deleted or new components added.

Second, the relationship, which is usually a mathematical function, is specified before the data is collected as depicting the "appropriate" relationship among the components and the judged variable (e.g., the ability to plan interdiction in Fig. 3). This appropriate mathematical function is usually some form of the subjective expected utility model. The current methods do not provide any basis for confirming or refuting that the function actually reflects respondents' perceptions of interrelationships among the variables.

Third, the subjective values used as input to the specified function are obtained through direct scaling methods for collecting judgments. Direct scaling methods have no provision for verifying the subjective scale values they produce. Hence, the true measures perceived by the respondents are indeterminate under the procedures.[2]

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[1] A detailed critique on current techniques is presented in Veit and Callero (1981).

[2] In a complex system, such as shown in Fig. 4, where there are many units like the one shown in Fig. 3, the preselected appropriate model is used to link these units together; thus, errors are perpetuated throughout the system.

Therefore, typical applications of subjective measurement being used today employ techniques and procedures that preclude interpretation of their results as reflecting respondents' perceptions. Even their attempt to produce optimal results by specifying prescriptive functions (i.e., functions assumed to be the way respondents "should" think or functions that would be "optimal" if applied by respondents) is suspect because their subjective input values are not and cannot be validated using their direct scaling methods.

Recognition of these problems, not a uniqueness of command and control, led us to realize that a new subjective measurement method needed to be developed to evaluate tactical air command and control and complex systems in general.

III. A SUBJECTIVE MEASUREMENT APPROACH FOR EVALUATING TACTICAL AIR COMMAND AND CONTROL AND OTHER COMPLEX SYSTEMS

We take the position that a subjective measurement method should be capable of testing the numerous causal hypotheses proposed throughout a complex system. These hypotheses encompass (a) the appropriateness of the components hypothesized to constitute a representation, (b) the models that are proposed to describe the experts' judgment processes, and (c) the measures that are proposed to be the subjective scale values associated with the components and outcomes.

Our approach to developing such a subjective measurement method for tactical air command and control and force employment has been to:

1. Use experimental design features from recently developed subjective measurement techniques that resolve the problems of testability and verifiability described in Sec. II and extend those techniques to handle special problems that occur with complex system analyses; and
2. Conduct a full scale application with a realistic tactical air command and control problem to demonstrate the approach and refine its application procedures.

The first step has already been taken. We have developed the Subjective Transfer Function (STF) approach to complex system analysis (Veit and Callero, 1981). This subjective measurement approach is summarized below. The second step is under way at this time. We are conducting experiments to obtain information regarding a tactical air

command and control and force employment problem that is of interest to the Air Force. The application procedures and experimental results will form a series of reports that include this Note, another addressing the development of the tactical air command and control and force employment representation (Callero, Naslund, and Veit, 1981) and a third addressing the results of our preliminary experiments (Veit, Rose, and Callero, 1981). Other reports will be forthcoming as the application progresses.

THE DEMONSTRATION PROBLEM

The demonstration problem was selected in conjunction with Air Force personnel from the Tactical Air Command, the Tactical Air Forces Interoperability Group (TAFIG), and Headquarters, Air Force, Studies and Analysis, who have cognizance over the development of evaluation methodology. The problem is to examine the value of enemy information to the effectiveness of command and control in employing tactical forces. It stems from the continuing development of several potential reconnaissance and surveillance systems that could significantly increase the amount and improve the quality of information about enemy second echelon forces provided to the tactical air command and control system. An important question is how better information can affect tactical air capabilities.

> Task Statement. Evaluate the effect of different levels of information about enemy ground forces on the capability of tactical air command and control to effectively employ tactical air against enemy second echelon targets. Consider a Korean-like theater conflict and enemy information levels ranging from what presently can be expected to what can be expected using enhanced collection systems.

Following the evaluation concepts set forth in Sec. I, effective employment of tactical air will be considered in terms of favorable influence on the outcome of the land battle.

Two initial steps in addressing this problem were to develop a conflict situation and an initial representation of tactical air command and control and force employment. The conflict situation forms the backdrop for consideration by respondents. A conflict situation that approximates a Korean conflict in terms of operational forces and scope of combat has been developed and is reported in Sec. IV. An initial representation also has been developed and is reported in detail in Volume II (Callero, Naslund, and Veit, 1981). Fig. 4 presents an overview of that representation.

Air Force personnel experienced in tactical air command and control and force employment will be identified to participate as respondents in areas of the investigation where they are most knowledgeable.

THE SUBJECTIVE TRANSFER FUNCTION APPROACH TO COMPLEX SYSTEM ANALYSIS

The subjective transfer function approach was developed to resolve measurement problems (described above) with subjective measurement techniques currently being used to evaluate complex systems. The approach incorporates features of the algebraic modeling approach to subjective measurement (Anderson, 1970, 1974; Birnbaum, 1974; Birnbaum and Stegner, 1979, 1980; Birnbaum and Veit, 1974a, 1974b; Krantz, Luce, Suppes, and Tversky, 1971; Rose, 1980; Veit, 1978) and provides additional design features necessary for analyzing complex systems where numerous variables affect important outcomes. The basic ideas behind

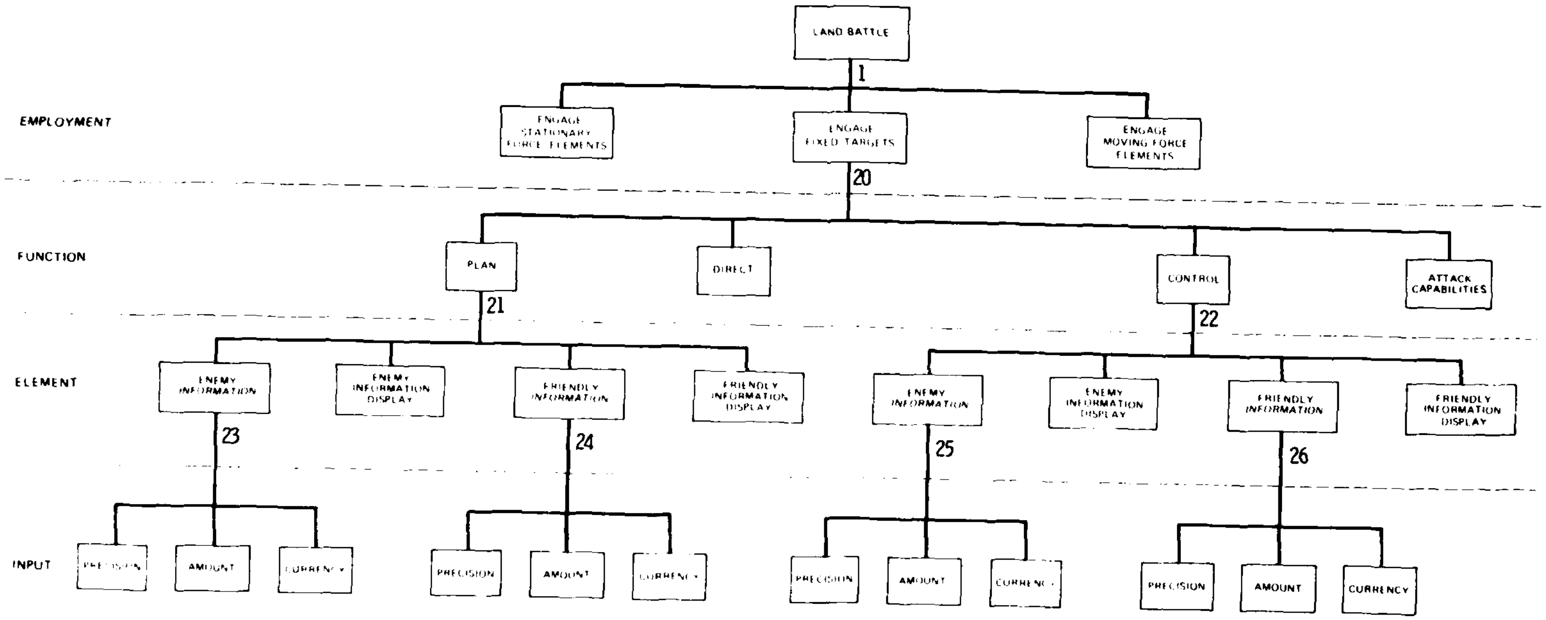

Fig. 4--Tactical air command and control and force employment representation

the subjective transfer function approach are outlined below. The tactical air command and control system shown in Fig. 4 is used to illustrate some of the ideas.

Formulating a System Representation

The first step in the STF approach is to formulate an initial representation of the system to be analyzed. It must be constructed so as to relate components of specific interest to system outcomes of specific interest. An initial complex system representation develops from experts' hypotheses. The numerous system hypotheses are represented by a hierarchical system structure similar to that shown in Fig. 4. For convenience, we have labeled the tiers *input*, *element*, *function*, and *employment*.

Components that do not have other components linked to them from a lower tier are referred to as *primitive*. In Fig. 4, primitive components include all components in the input tier, the "Enemy Information Display" and "Friendly Information Display" components in the element tier, and the "Direct" and "Attack Capabilities" components in the function tier.

Every nonprimitive component represents a hypothesized system outcome, each of which identifies an *experimental unit* that links to the outcome the components hypothesized to affect it. Three to five components are hypothesized to affect each outcome. For example, there are eight experimental units (numbered 1 and 20 through 26) in Fig. 4. In experimental unit 23, Precision, Amount, and Currency are hypothesized to affect Enemy Information; in experimental unit 21, Enemy

Information, Enemy Information Display, Friendly Information and Friendly Information Display are hypothesized to affect Plan.

Components that are hypothesized to affect a system outcome directly are the independent variables in experiments investigating their effects on that outcome. For each of these components we determine four or five descriptive levels spanning the "best" to "worst" expected quality, condition, or capability relevant to the component. This constructional feature makes it possible to generate questionnaires from experimental designs that allow tests of main and interaction effects of the components on judgments, as well as tests of hypothesized models (referred to as subjective transfer functions for reasons described below) that specify the nature of these effects.

An important feature in constructing a representation and delineating experimental units is that each nonprimitive component, other than the Land Battle, is included in two experimental units. These components serve as a dependent variable (the dimension to be judged) in one unit and as an independent variable (a variable to be experimentally manipulated) in the unit next highest in the hierarchy to which it is linked. For example, Enemy Information is a dependent variable for unit 23 but an independent variable in unit 21. This constructional feature is important to the process of developing mathematical functions that link together the components of a representation.

The system representation evolves iteratively as the hypotheses are tested. Inclusion or exclusion of hypothesized system components depends on how meaningful they are to the respondent population and

their empirical effects on judged outcomes. When components initially selected to define a system do not affect judgments of hypothesized outcomes (determined through statistical analyses), they are eliminated from the representation and new components are tested.

Obtaining Subjective Transfer Functions

Subjective transfer functions are obtained by conducting tests of subjective models in each experimental unit separately. The models specify the relationship between the independent and dependent variables. When a model is found that accounts for the judgment data, subjective scale values of the components associated with the independent and dependent variables are derived from it. The model that explains the judgment data is the validational base for the scale values, which are "correct" because the model from which they were derived was tested and verified.

The transfer feature of hypothesized judgment models comes from the operational definitions of components that serve as both dependent and independent variables. These components are defined in the same terms when they are dependent variables as when they are independent variables. For example, Enemy Information would be defined in the same way when it is a dependent variable (experimental unit 23) for the independent variables Precision, Amount, and Currency as when it is an independent variable being manipulated with the other three independent variables Enemy Information Display, Friendly Information, and Friendly Information Display (experimental unit 21) for the dependent variable Plan. This design feature serves as a basis for treating the verified

models as transfer functions (T) when they are used to compute predicted outcomes in complex system analyses.

Because the representation evolves iteratively as the hypotheses represented by the experimental units are tested, the hypotheses should be tested, and appropriate subjective transfer functions determined, from the top down in the representation to avoid unneccessary effort. This avoids conducting an experiment on a hypothesis represented by an experimental unit having a nonprimitive component dependent variable before that component is confirmed to be relevant by a test on the experimental unit in which the component is an independent variable. For example, before one conducts a test of the hypothesis represented in experimental unit 20 in Fig. 4 (where Engage Fixed Targets is the dependent variable), one should conduct a test of the hypothesis represented in experimental unit 1 (where Engage Fixed Targets is an independent variable) to confirm that the Engage Fixed Targets component affects the judgments of the respondents concerning the outcome of a land battle and, hence, will be included in the representation.

Systems Comparison

After transfer functions have been obtained for all experimental units in a representation, different systems having the same representation can be compared on the outcomes by using the transfer functions to compute predicted outcomes for each system under investigation. This is a three step process: (1) define each system, (2) determine subjective values associated with the definitions, and (3) use the subjective transfer functions to compute predicted outcomes for each system. We discuss each step in turn.

Each system is defined by specifying a particular descriptive level for each of the primitive components that reflects its quality, condition, or capability. For example, the Currency of enemy information may be "30 minutes" in one system and "3 hours" in another because the systems have different collection and processing techniques. Or, one system may have fully automated Friendly Information Display while another may not. The descriptive levels defining a system can, but need not, be the same levels used in the experiments from which the transfer functions were obtained.

Once a system is defined, subjective input values associated with primitive component descriptions are needed to compute the transfer functions. These can be obtained in one of three ways.

1. If component descriptions are <u>the same</u> as those used in the experiments, their scale values are known and are part of the experimental data; they are the values derived from the transfer functions.
2. If the component descriptions are <u>physical measures</u> (e.g., time, number) not used in the experiment, their subjective counterparts can be obtained from the psychophysical function, which relates physical to subjective values and is derived from the transfer function along with the scale values. It is part of the experimental data.
3. If component descriptions are <u>qualitative</u> (i.e., written) descriptions not used in the experiment, preevaluation

experiments, like the original experiments for those units, need to be performed in order to obtain the necessary scale values.

When all subjective values associated with primitive components are obtained, the network of transfer functions is used to compute predicted outcomes for each system under investigation, as follows. Subjective input values used to compute transfer functions are obtained from primitive components or from transfer functions one tier lower in the hierarchy to which they are linked. For example, subjective input values needed to compute T23 (the transfer function for experimental unit 23) would be obtained from the subjective values associated with the system's definitional descriptive levels for the primitive components Precision, Amount, and Currency. For another example, the subjective input values needed to compute T21 would be obtained from the transfer functions T23 and T24 for Enemy Information and Friendly Information, respectively, and also from the subjective values associated with the system's description levels for the primitive components Enemy Information Display and Friendly Information Display.

Computing the transfer functions yields predicted system outcomes as perceived by the respondent population. Outcome comparisons provide a way to compare systems that differ in one or more primitive components. That is, they provide a way to assess how different levels of the primitive components alter outcomes throughout the system and the overall system outcome (e.g., the Land Battle). This makes it possible to identify components or component combinations that are perceived to be instrumental in achieving desired effects on the outcomes.

<u>Summary</u>

The STF approach stresses the idea of hypothesis testing. Hypotheses are tested concerning effects of defined system components on specified outcomes, as are hypothesized models that specify the nature of these effects. The final complex system representation emerges only after empirical support has been obtained for the effects of all hypothesized components on judged outcomes. Judgment experiments continue within each experimental unit until a transfer function is found that explains the relationships among the components. Transfer functions are considered "appropriate" when the data support their predictions. Subjective scale values of independent and dependent variables are derived from an appropriate model. Thus, the approach enables the use of <u>valid</u> subjective input values to compute <u>valid</u> subjective models in determining and comparing system outcomes.

The subjective transfer function approach represents a major advancement in the state of the art for applying subjective measurement to complex analysis. In this approach, conclusions about system effects on important outcomes are based on tested and verified premises.

IV. DEMONSTRATION PROBLEM CONFLICT ENVIRONMENT

In this section we describe a "Red/Blue "conflict situation to provide the setting for the respondents to consider in determining their responses to questions concerning command and control and use of tactical air.[1] The material is presented in a way that approximates an air or ground operations order and is similar in this respect to the situation provided to the respondents.

We first present background to the conflict situation, then organization aspects of blue and red ground and air forces. This is followed by a summary of the ground and air situation, concepts of operations for D+2, and some concluding remarks to highlight what we have intended for the respondent.

BACKGROUND

Red and Blue have a history of intermittent conflict, with Red the aggressor.

The historical invasion route is down Red Valley, on the rolling terrain and high-speed avenues of approach to A and B Cities (Fig. 5).

Numerous low-level armed clashes routinely occur, but the past six months saw increases in both the level and number of incidents instigated by Red. During this period, extensive force and logistics buildups occurred with large concentrations in the Red Valley area

[1] This exemplary situation is not intended to agree with any actual scenario or planned force deployment. It is a "red-blue" situation, occurring in a hypothetical combat zone, developed only for our study purposes.

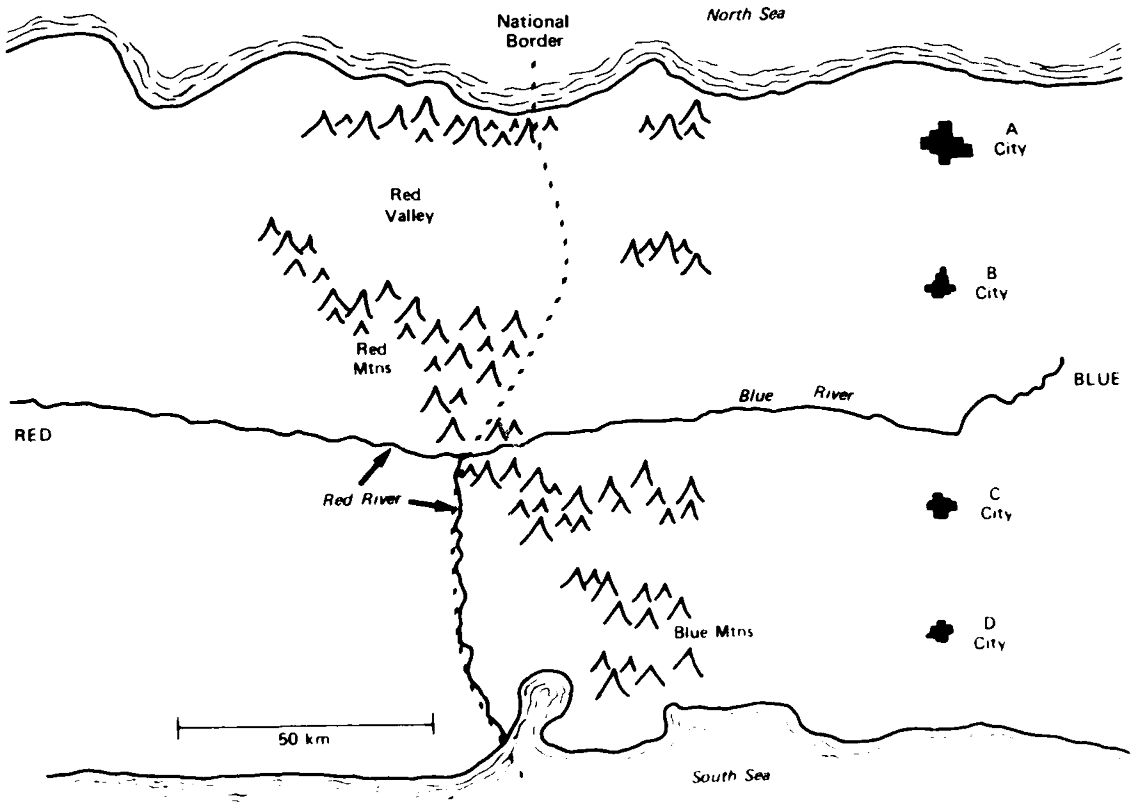

Fig. [illegible]--Red and Blue areas of operations

adjacent to the approaches to A and B Cities. Intelligence sources reported Red ground and Air forces were fully mobilized and were deployed to attack positions.

Blue responses to Red actions were to declare a general alert (the highest state of alert short of conflict), deploy ground and air forces to defense positions and bases, and activate the Blue Tactical Air Control System (Blue TACS).

Red ground and air forces attacked at 0600 on D-day.

BLUE ORGANIZATION

Blue Ground Forces

Blue ground force organization on D-day is shown in Table 1.

Table 1

BLUE GROUND FORCE ORGANIZATION

CINCBLUE

Blue Army

1st Corps	2nd Corps	Reserve
6 Mechanized Divisions	3 Mechanized Divisions	2 Mechanized Divisions
1 Armored Division	1 Armored Division	4 Mechanized Battalions
4 Tank Battalions	1 Tank Battalion	
2 Special Forces Bdes	1 Special Forces Bde	
30 Artillery Battalions	20 Artillery Battalions	

Blue Air Force Command and Control

Blue Air Force command and control organization on D-day is shown in Table 2. Figure 6 shows the locations of Blue Air Force command and control facilities.[2]

The Tactical Air Control Center (TACC) controls two Control and Reporting Centers (CRCs). These are the radar control facilities responsible for the management of the air defense battle and the airspace over the combat zone.

The CRCs each have two subordinate Control and Reporting Posts (CRPs) that further decentralize air defense and airspace control. The CRPs can take over functions of the CRCs if the latter are disabled.

Table 2

BLUE AIR FORCE COMMAND AND CONTROL ORGANIZATION

CINCBLUE			
Blue Air Force			
Blue Tactical Air Control Center			
Control & Reporting Centers (2)	Wing OPS Centers	1st Corps Air Support OPS Center	2nd Corps Air Support OPS Center
Control & Reporting Posts (4)		Tactical Air Control Parties	Tactical Air Control Parties

[2]Location of the wing operations centers is not shown.

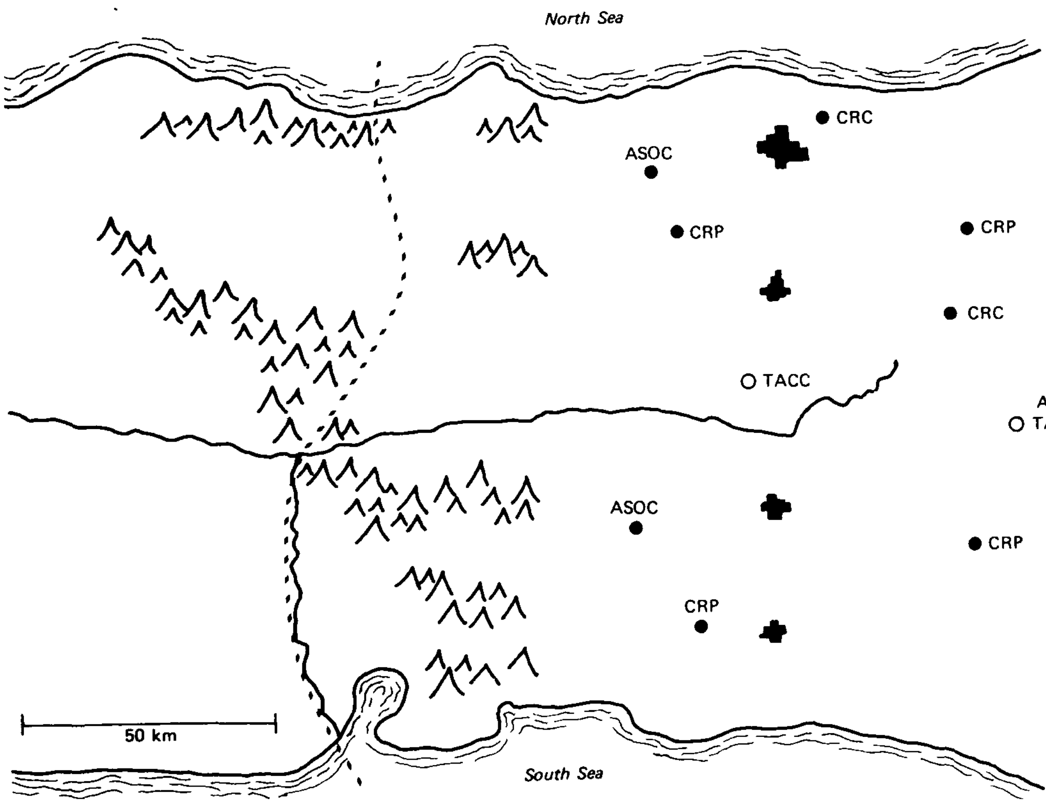

Fig. 6--Blue Air Force command and control facilities

To support the ground forces, there are two Air Support Operations Centers (ASOCs) that operate with the tactical operations centers of the two Blue Army Corps. The subordinate elements of these ASOCs are the Tactical Air Control Parties, and there is one of these operating with each Blue Army echelon down to battalion level.

The Wing Operations Centers (WOCs) are located at the airfields to manage detailed strike planning, launch, and recovery of the tactical aircraft.

RED ORGANIZATION

Red Ground Force Organization

Under CINCRED, there are four combined arms armies (CAAs). See Table 3. Each CAA compares to the Blue corps organization, having about

Table 3

RED GROUND FORCE ORGANIZATION

CINCRED				
1st CAA	2nd CAA	3rd CAA	4th CAA	Reserve
3 Motorized Rifle Divisions	3 Motorized Rifle Divisions	3 Motorized Rifle Divisions	6 Motorized Rifle Divisions	6 Motorized Rifle Divisions
1 Tank Division	1 Tank Division	1 Tank Division	1 Tank Regiment	1 Tank Division
1 Armored Regiment				4 Tank Regiments

75 percent of Blue manning and armored fighting vehicles (tanks and APC equivalents).

Red Air Force Organization

Red has six fighter divisions, with 565 ground attack and 130 air defense fighter aircraft available on D-Day. (Initial Blue aircraft capability is 360, increasing to 555 at D+2 when augmentation is complete.)

GROUND/AIR SITUATION THROUGH 0600/D+2

D-Day

Red forces attacked with 12 reinforced divisions in the north and six reinforced divisions in the south. There were seven reinforced second echelon divisions available for commitment to either zone.

Blue Army defended with 1st Corps in the north and 2nd Corps in the south to meet Red attacks on four avenues of approach (A, B, C, and D). (See Fig. 7.)

The major Red attack was in the north along avenue A to A City. A supporting attack was launched along Avenue B to B City. Attacks on Avenues C and D were primarily fixing attacks.

The Blue defensive concept was to destroy Red forces forward of line Foxtrot, delaying penetration of this line as long as possible. There are two phases to this concept: Phase 1 commenced at 0600/D-day, requiring a fight in the vicinity of line Foxtrot to destroy enemy forces attempting penetration of this line. Phase 2 will be a

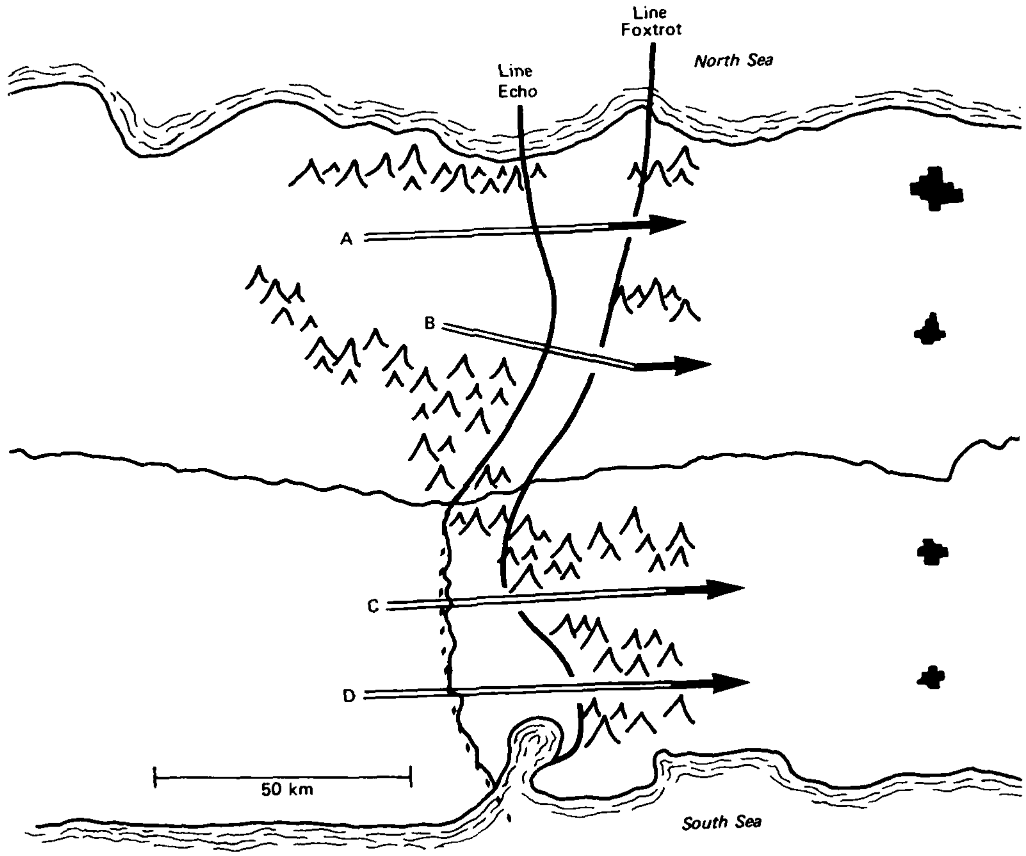

Fig. 7--Avenues of Red approach

counterattack to restore the Blue boundary, with forces prepared to continue the attack into Red on order.

Current Situation (0600/D+2)

In the 1st corps sector, the ground situation in the vicinity of A City is critical (Fig. 8). Red has penetrated line Foxtrot in several places, and is threatening the defenses forward of A City. There are three Red CAA attacking with major elements of 12 divisions. Red reinforcements (three motorized rifle and one tank division) are moving along avenue A in the vicinity of line Echo. These reinforcements have approximately 2500 armored fighting vehicles.

The 2nd corps sector is holding at line Foxtrot, where the 1st Red CAA, with elements of six reinforced motorized rifle divisions, is attacking.

Blue Ground Force Mission and Concept

The First Corps task is to contain the penetration on Avenue A, holding at line Foxtrot. Second Corps continues a delay to line Foxtrot in its sector, then holds. CINCBLUE has given priority of tactical air support to the 1st Corps.

Blue Air Force Mission and Concept

The Blue Air Force mission is to defend Blue forces and installations against Red air attacks, conduct close air support (CAS) operations in support of Blue Army, and attack Red second echelon forces. Secondary efforts are to conduct air interdiction (AI) and

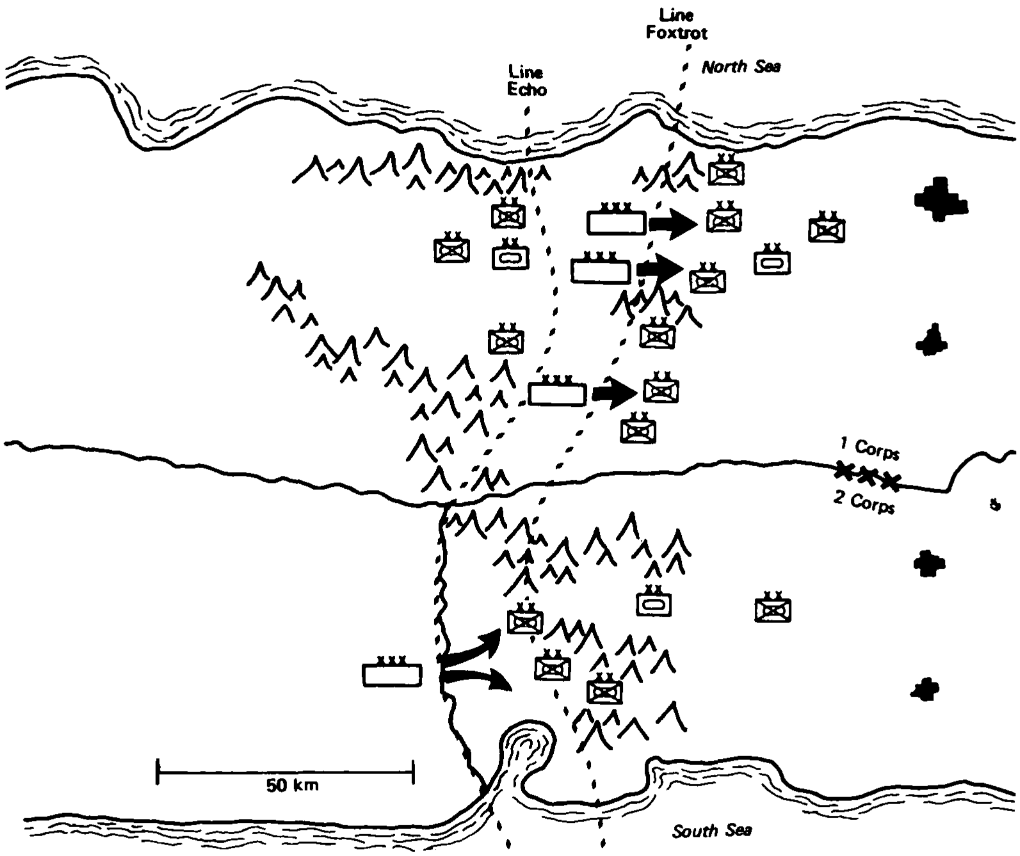

Fig. 8--Ground situation 0600/D+2

offensive counter air operations against Red installations and forces. As the land battle stabilizes and air superiority is obtained, priority of tactical air effort will be to second echelon attack operations.

In the final phase (restoration of Blue boundary and subsequent continuation of attack into Red), first priority of tactical air missions will be to CAS, with second priority to AI.

Blue air order of battle for D+2 is shown in Table 4. Blue air sortie allocations are shown in Table 5.

Table 4

BLUE AIR ORDER OF BATTLE ON D+2[a]

F-4	F-15	F-16	TOTAL
252	59	189	500

[a]Blue aircraft attrition through D+2 has been 10 percent.

Table 5

BLUE TACTICAL AIR SORTIE ALLOCATIONS 0600/D+2

	Close Air Support	Air Defense	Second Echelon Attack
1st Corps	125		250
2nd Corps	50		75
TACC		100	50
Total Sorties	175	100	375

Blue Air Operations Areas

As illustrated in Fig. 9, the Blue Air Force area of operations is divided into three areas: (1) the Combat Zone (from the Blue rear area out to the range of ground force direct fire weapons); (2) the second echelon attack area (from approximately 10-15 kilometers west of the line of contact (currently line Foxtrot) to a distance beyond the Fire Support Coordination Line (now established on line Echo); and (3) the area beyond, where air interdiction operations are conducted. Target selection for close air support is the responsibility of each of the two Corps, operating through their collocated ASOCs. Blue Army elements may also request strikes against targets in the second echelon and AI areas. These latter strikes are planned and controlled by the TACC but they are coordinated with Blue Army operations.

Target Types

Table 6 shows the types of target arrays considered by the TACC strike planners.

The fixed targets that are of importance to the Red second echelon forces moving near line Echo are of course extremely significant as they are essential to the movement of these forces. The moving force elements themselves, especially the armored fighting vehicles, are priority second echelon targets as well. And those force elements presently not moving--perhaps in assembly areas near line Echo, are also candidates for air strike targeting by the TACC.

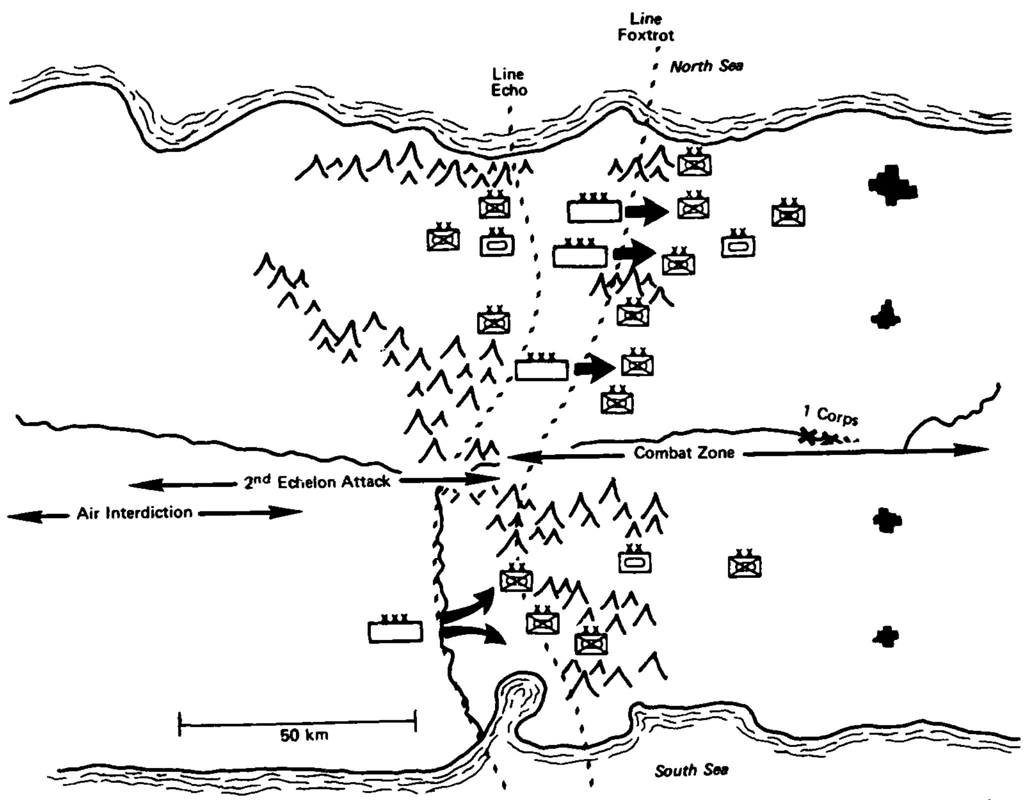

Fig. 9--Blue air operations areas

Table 6

TARGET TYPES

Fixed Targets	Moving Force Elements	Stationary Force Elements
LOC choke points	Armor	Same as moving force elements
Bridges	APCs	
Hillside cuts	Trucks	
Crossing sites	Personnel	
Structures	Radars	
Caves/Tunnels	AAA/SAMs	
Pipelines	Artillery	
Fixed commo nodes	C2 Facilities	
Fixed radar sites		
Fixed SAM sites		
Bridges		
Crossing Sites		
Road Junctions		
Supply Points		

Logistics

Table 7 shows the status of selected logistics support items.

Table 7

BLUE AIR FORCE LOGISTICS STATUS

POL	Adequate
Munitions	Overall adequate through D+20 Limited Air-Ground Missiles
Transportation	Adequate
Base Development	Adequate. Augmentation resources are "Bare Base" status

Weather

Table 8 summarizes the expected weather for D+2.

Table 8

WEATHER STATUS D+2/0600

CURRENT WEATHER
8000 feet scattered to broken cumulus
Cloud tops 9 to 11,000 feet
Winds light, 200-270 degrees at 6-8 knots
Visibility 6-12 miles
Temperature 70 degrees F
FORECAST
No change for 36 hours

COMMENTS ON THE CONFLICT ENVIRONMENT

The conflict environment sketched out above is intended to provide a backdrop for respondents to use to formulate perceptions about causal relationships among the components of tactical air command and control and force employment. It is deliberately general to avoid scenario specific interpretations of the results but is intended to contain sufficient information to bring the important aspects of a conflict situation to the attention of the respondent, such as the following:

- o A general image of the conflict--the antagonists, the geographical setting.
- o Factors that affect planning for and conduct of air operations-- weather, logistics status, command and control structure.

- The scope of the conflict--number and size of forces, dimensions of the battlefield.
- A general notion of the situation as conflict commences or a representative day of the conflict (chosen to be D+.
- A concept of where and how tactical airpower is to operate on a representative day.
- The kinds of target arrays which must be considered in planning and conducting tactical air operations against second echelon targets on a representative day.

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